

Coordinate Descent

Nipun Batra

IIT Gandhinagar

July 29, 2025

random, round-robin

No step-size to choose!

Converges for Lasso objective

Coordinate Descent : Example

Learn $y = \theta_0 + \theta_1 x$ on following dataset, using coordinate descent where initially $(\theta_0, \theta_1) = (2, 3)$ for 2 iterations.

x	y
1	1
2	2
3	3

Coordinate Descent : Example

Our predictor, $\hat{y} = \theta_0 + \theta_1 x$

Error for i^{th} datapoint, $\epsilon_i = y_i - \hat{y}_i$

$$\epsilon_1 = 1 - \theta_0 - \theta_1$$

$$\epsilon_2 = 2 - \theta_0 - 2\theta_1$$

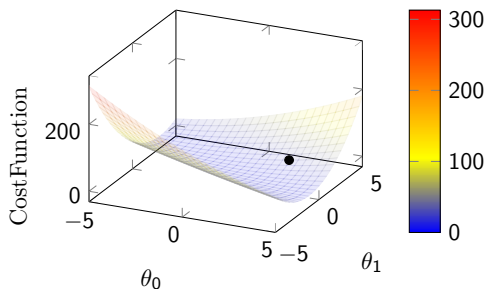
$$\epsilon_3 = 3 - \theta_0 - 3\theta_1$$

$$\text{MSE} = \frac{\epsilon_1^2 + \epsilon_2^2 + \epsilon_3^2}{3} = \frac{14 + 3\theta_0^2 + 14\theta_1^2 - 12\theta_0 - 28\theta_1 + 12\theta_0\theta_1}{3}$$

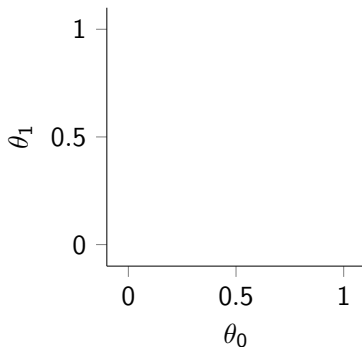
Iteration 0

$$\text{MSE} = \frac{1}{3}(14 + 3\theta_0^2 + 14\theta_1^2 - 12\theta_0 - 28\theta_1 + 12\theta_0\theta_1)$$

Surface Plot



Contour plot, view from top



Coordinate Descent : Example

Iteration 1

INIT: $\theta_0 = 2$ and $\theta_1 = 3$

$\theta_1 = 3$ optimize for θ_0

Coordinate Descent : Example

Iteration 1

INIT: $\theta_0 = 2$ and $\theta_1 = 3$

$\theta_1 = 3$ optimize for θ_0

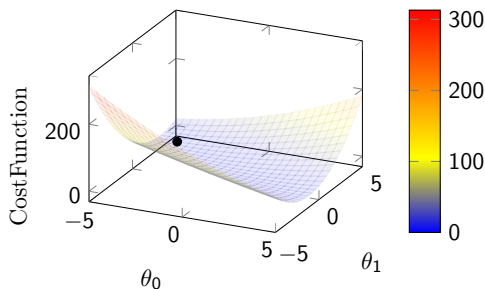
$$\frac{\partial \text{MSE}}{\partial \theta_0} = 6\theta_0 + 24 = 0$$

$$\theta_0 = -4$$

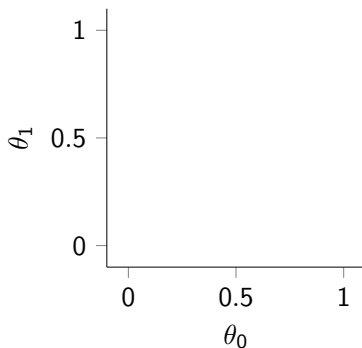
Iteration 1

$$\text{MSE} = \frac{1}{3}(14 + 3\theta_0^2 + 14\theta_1^2 - 12\theta_0 - 28\theta_1 + 12\theta_0\theta_1)$$

Surface Plot



Contour plot, view from top



Coordinate Descent : Example

Iteration 2

INIT: $\theta_0 = -4$ and $\theta_1 = 3$

$\theta_0 = -4$ optimize for θ_1

Coordinate Descent : Example

Iteration 2

INIT: $\theta_0 = -4$ and $\theta_1 = 3$

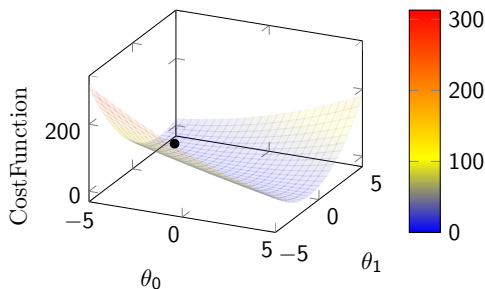
$\theta_0 = -4$ optimize for θ_1

$\theta_1 = 2.7$

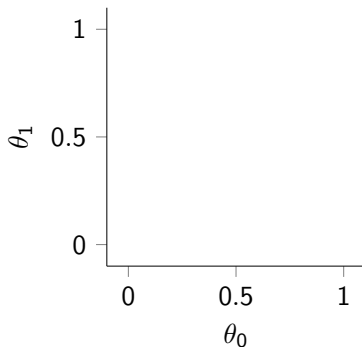
Iteration 2

$$\text{MSE} = \frac{1}{3}(14 + 3\theta_0^2 + 14\theta_1^2 - 12\theta_0 - 28\theta_1 + 12\theta_0\theta_1)$$

Surface Plot



Contour plot, view from top



Coordinate Descent : Example

Iteration 3

INIT: $\theta_0 = -4$ and $\theta_1 = 2.7$

$\theta_1 = 2.7$ optimize for θ_0

Coordinate Descent : Example

Iteration 3

INIT: $\theta_0 = -4$ and $\theta_1 = 2.7$

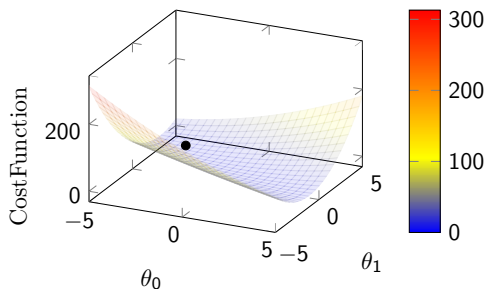
$\theta_1 = 2.7$ optimize for θ_0

$\theta_0 = -3.4$

Iteration 3

$$\text{MSE} = \frac{1}{3}(14 + 3\theta_0^2 + 14\theta_1^2 - 12\theta_0 - 28\theta_1 + 12\theta_0\theta_1)$$

Surface Plot



Contour plot, view from top

